ARTICLES WHICH INCLUDE CHEVRON FILM COOLING HOLES, AND RELATED PROCESSES

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH & DEVELOPMENT

[0001] This invention was made with Government support under contract number DE-FC26-05NT42643, awarded by the Department of Energy. The Government has certain rights in the invention.

BACKGROUND

[0002] The general subject matter of this invention relates to gas turbine engines, and, more specifically, to structures for cooling various components of the engines.

[0003] A gas turbine engine includes a compressor, in which engine air is pressurized. The engine also includes a combustor, in which the pressurized air is mixed with fuel, to generate hot combustion gases. In a typical design (e.g., for aircraft engines or stationary power systems), energy is extracted from the gases in a high pressure turbine (HPT) which powers the compressor, and in a low pressure turbine (LPT). The low pressure turbine powers a fan in a turbofan aircraft engine application, or powers an external shaft for marine and industrial applications.

[0004] The need for cooling systems in gas turbine engines is critical, since the engines usually operate in extremely hot environments. For example, the engine components are often exposed to hot gases having temperatures up to about 3800° F. (2093° C.), for aircraft applications, and up to about 2700° F. (1482° C.), for the stationary power generation applications. To cool the components exposed to the hot gases, these "hot gas path" components typically have both internal convection and external film cooling.

[0005] In the case of film cooling, a number of cooling holes may extend from a relatively cool surface of the component to a "hot" surface of the component. The cooling holes are usually cylindrical bores which are inclined at a shallow angle, through the metal walls of the component. Film cooling is an important mechanism for temperature control, since it decreases incident heat flux from hot gases to the surfaces of components. A number of techniques may be used to form the cooling holes; depending on various factors, e.g., the necessary depth and shape of the hole. Laser drilling, water jet cutting, and electro-discharge machining (EDM) are techniques frequently used for forming film cooling holes. The film cooling holes are typically arranged in rows of closely-spaced holes, which collectively provide a large-area cooling blanket over the external surface.

[0006] The coolant air is typically compressed air that is bled off the compressor, which is then bypassed around the engine's combustion zone, and fed through the cooling holes to the hot surface. The coolant forms a protective "film" between the hot component surface and the hot gas flow, thereby helping protect the component from heating. Furthermore, protective coatings, such as for example, thermal barrier coatings (TBCs), may be employed on the hot surface to increase the operating temperature of the components.

[0007] Film cooling is highest when the coolant flow "hugs" the hot surface. With this in mind, many different surface geometries and shapes have been designed for the exit region of the cooling holes. Examples include different types of trenches and craters, which are purposefully formed on one or more of the component surfaces. These surface features can enable a longer duration of contact between the coolant flow and the hot surface, and/or can provide a cooler, effective gas temperature layer on the surface.

[0008] Various considerations are important in designing the most appropriate film cooling system. For example, a certain volume of air is usually required to flow over the hot surface of the component, and as described above, it is also important that a significant portion of that air stay attached to the hot surface, for as long as possible. Moreover, since a large number of film cooling holes require a larger amount of air to be bled off the engine compressor, engine efficiency may suffer if too many cooling holes are present. Furthermore, since future turbine engine designs may involve even higher operating temperatures, improved film cooling systems may take on even greater importance.

[0009] With these considerations in mind, new methods and structures for improving film cooling capabilities in gas turbine engines would be welcome in the art. The innovations should enhance the performance of the cooling stream, without significantly decreasing engine efficiency. The film cooling structures should also not interfere with the strength and integrity of the turbine engine part. Moreover, the new film cooling structures should be capable of being formed, accurately and efficiently, by one or more of the drilling, cutting, and machining techniques mentioned above.

BRIEF DESCRIPTION OF THE INVENTION

[0010] In one embodiment of the invention, an article in the form of a substrate is disclosed, comprising an inner surface which can be exposed to a first fluid; and including an inlet; and an outer surface spaced from the inner surface, which can be exposed to a hotter second fluid. The article further includes at least one row or other pattern of passage holes, wherein each passage hole includes an inlet bore extending through the substrate from the inlet at the inner surface to a passage hole-exit proximate to the outer surface, with the inlet bore terminating in a chevron outlet adjacent the hole-exit. The chevron outlet comprises a pair of wing troughs having a common surface region between them; wherein the common surface region comprises a valley which is adjacent the hole-exit; and further comprises a plateau adjacent the valley.

[0011] Another embodiment is directed to a film-cooled airfoil or airfoil region configured with one or more chevron film cooling holes. The airfoil or airfoil region comprises:

- **[0012]** a) at least one inner surface exposed to a first fluid; and including an inlet;
- **[0013]** b) an outer surface spaced from the said inner surface, and exposed to a hotter second fluid; and
- **[0014]** c) at least one row or other pattern of passage holes, wherein each passage hole includes an inlet bore extending partially through the substrate from the inner surface to a passage hole-exit proximate to the outer surface, with the inlet bore terminating in a chevron outlet, as described herein.

[0015] Still another embodiment is directed to a method for the formation of a row or other pattern of passage holes in a substrate which includes an inner surface and an outer surface spaced from the inner suface, and further comprises an inlet bore extending at least partially between the two surfaces, said inlet bore terminating in a chevron outlet adjacent a hole-exit proximate to the outer surface, wherein the chevron outlet comprises a pair of wing troughs having a common